Biological Synopsis of the Rusty Crayfish (*Orconectes rusticus*)

I.D. Phillips

Central and Arctic Region
Fisheries and Oceans Canada
Burlington, ON L7R 4A6

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by

I.D. Phillips[1]

Central and Arctic Region
Fisheries and Oceans Canada
Burlington, ON L7R 4A6

[1]# 625 4th Avenue, Saskatoon, SK S7K 2M8

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The Rusty Crayfish (*Orconectes rusticus*) is a hardy and aggressive invader that has the potential to impart dramatic change on Canada's aquatic ecosystems if its spread is left unchecked. Originally from the Ohio River Basin, *O. rusticus* has spread from New Mexico to Maine in the United States and as far north as the Province of Ontario. Typically, this species is transported through live bait fisheries into new watersheds and once established, is able to expand its range through connecting waterways. In Ontario, its presence in the Lake of the Woods was first noted in 1963, and since then populations have been found in the Kawartha Lakes Region, the Lake Superior watershed, and, most recently, expanding down the Winnipeg River into Manitoba. Although dramatic ecosystem – scale effects have been documented in many American waterbodies where this species has invaded, there is a paucity of studies on the effect this species may currently be having on aquatic ecosystems here in Canada.

RÉSUMÉ

Phillips, I.D. 2010. Biological synopsis of the Rusty Crayfish (*Orconectes rusticus*).
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L'écrevisse américaine (*Orconectes rusticus*) est une espèce envahissante rustique et agressive qui peut provoquer des changements importants dans les écosystèmes aquatiques canadiens si aucune mesure n'est prise pour limiter son expansion. Originaire du bassin de l'Ohio, *O. rusticus* s'est propagé depuis le Nouveau-Mexique jusqu'au Maine, aux États-Unis, et aussi loin qu'en Ontario, au nord. D'ordinaire, les individus de l'espèce sont transportés dans de nouveaux bassins hydrographiques par les pêcheurs au poisson-appât; une fois établis, ils peuvent poursuivre leur expansion par des voies d'eau communicantes. En Ontario, on a relevé la présence de l'espèce pour la première fois en 1963 dans le lac des Bois et, depuis ce temps, des populations ont été observées dans la région des lacs Kawartha, dans le bassin hydrographique du lac Supérieur et, plus récemment, dans la rivière Winnipeg, au Manitoba. Bien que les effets marqués de l'espèce sur l'écosystème de nombreux bassins hydrographiques américains aient été documentés, les études sur l'incidence que celle-ci peut avoir présentement sur les écosystèmes aquatiques canadiens sont rares.

INTRODUCTION

The United States has witnessed a dramatic range expansion of *Orconectes rusticus* over the past half century and experience gained there (e.g., Wilson et al. 2004) may be helpful in understanding current range expansions in Canada. Originally described from the Ohio River at Cincinnati, *O. rusticus* is thought to be endemic to the Ohio River and its tributaries in Ohio, northern Kentucky, and Indiana (Creaser 1931, Page 1985). Through introduction largely attributable to its use as fishing bait (Hobbs III et al. 1989, Page 1985) the species is known to have expanded its range to at least half a dozen other states (Taylor and Redmer 1996), and to Ontario (Crocker and Barr 1968) and Manitoba (Lowdon, unpublished; D. Watkinson, pers. comm..) here in Canada. Now that *O. rusticus* is established in Canadian watersheds, aquatic corridors and bait-bucket introductions present the next greatest potential risk for crayfish range expansion (Phillips et al. 2009).

The most notable difference in ecosystem impact between *O. rusticus* and crayfish species native to Canada is the magnitude of macrophyte disturbance the Rusty Crayfish can have in lakes and rivers. Although native species such as *O. virilis* Hagen can reduce macrophyte abundance (Chambers et al. 1990), *O. rusticus* eliminates whole macrophyte beds beyond what effects are realized with *O virilis* as is evident by their additional impact on aquatic plants in lakes that already possess *O. virilis* (Wilson et al. 2004). Such large-scale macrophyte removal may also indirectly result in large reductions of macroinvertebrates, changes to fish habitat, and may even destabilize the aquatic ecosystem. Wherever this species has become established, it has altered aquatic ecosystems and reduced populations of native crayfishes (Butler and Stein 1985, Lodge et al. 1985, 1994, 2000, Butler 1988, Olsen et al. 1991, Taylor and Redmer 1996, McCarthy et al. 2006). This synopsis presents the biological characteristics, the ecology and the known impacts of *O. rusticus* invasion.

NAME AND CLASSIFICATION

From IT IS database (2008).

Kingdom:	Animalia
Phylum:	Arthropoda
Subphylum:	Crustacea, Brünnich, 1772
Class:	Malacostraca, Latreille, 1802
Subclass:	Eumalacostraca, Grobben, 1892
Superorder:	Eucarida, Calman, 1904
Order:	Decapoda, Latreille, 1802
Suborder:	Pleocyemata, Burkenroad, 1963
Family:	Cambaridae, Hobbs, 1942
Genus:	*Orconectes*, Cope, 1872
Species:	*Orconectes rusticus* (Girard, 1852)

Common scientific name: *Orconectes rusticus* (Girard, 1852)

Common English name: Rusty Crayfish
Common names in other languages: none

Voucher Specimens: Unknown. Holotype likely destroyed in the Chicago fire of 1871 (Faxon 1914).

DESCRIPTION

VISUAL ASPECT

Adults reach a maximum length of ~11 cm (Fig. 1). Males are larger than females upon maturity and both sexes have larger, broader chilipeds than other crayfishes in the waterbodies it has invaded in Canada. Dark "rusty" spots are usually apparent on either side of the carapace, however, these are not exclusively diagnostic as they are not always present in all populations. Claws are generally smooth, with grayish-green to reddish-brown colouration and often a dark band on the proximate end of the chiliped (Fig. 2).

MORPHOLOGICAL DETAILS

The most detailed accounts of *Orconectes* crayfish morphology and distinguishing characteristics are provided by Crocker and Barr (1968) and Fetzner (2006). The taxonomic classification of the *O. rusticus* given by Crocker and Barr (1968) is based on the morphology of the adult male, of which, there occur two distinct forms. The forms interchange periodically throughout the adult life of the crayfish, one the sexually capable and the other an intermediate stage resembling juvenile characteristics. Characteristically, form I presents increased sclerotization of external features relative to form II, and stronger, more robust ischial spines (i.e., pronounced copulatory organ; Fig. 3 [A] vs 3 [B], respectively; Crocker and Barr 1968). As described by Crocker and Barr (1968), form I male *O. rusticus* morphology is as follows:

Carapace (Fig. 4):

- A deep cervical groove, sinuate, and broken on sides.
- Postorbital ridges short, grooved on outer aspect, terminating in a short but sharp spine.
- Areola wide, typically with three or more punctations side by side in narrowest portion.
- Cylindrical while flattened in dorsal aspect.

Antennal Scale:

- Equal in length to the rostrum, widest from proximal to middle.

Antennal Flagellum:

- Stout, about as long as the length of the body.

Epistome:

- Triangular, about equal in length as its breadth, sides convex, apex blunt with median tooth.

Chela (Fig. 5):

- Large, the medial border of propodus tuberculate, fingers and hand ornamented with numerous punctations, fingers gaping at base. Immoveable finger sometimes slightly bearded, movable finger somewhat sinuate with an incurved tip.
- Carpus of the chiliped is characterized by a shallow furrow on the dorsal surface; short, strong spine on the medial surface, low spine or strong tubercle in centre of distal margin on ventral side.

Merus:

- Bears two small spines at distal end dorsally. Two stronger spines beneath sometimes containing several smaller ones too.

Telson:

- Wide, and proximal section bispinose on each side, while distal section with straight to slightly concave posterior margin.
- Distal section shorter then proximal.

Ischial Hooks:

- On third pereiopods.

Female *O. rusticus* are quite similar to the males of form I, but are characterized in ventral aspect by their oval seminal receptacle, bituberculate on anterior margin, with deep median depression, posterior wall is raised into a median tubercle divided by very narrow sinuous fissure (from Crocker and Barr 1968).

O. rusticus is distinguished from other often co-occurring *Orconectes* crayfish most easily by the copulatory organ of the males. In *O. rusticus*, the male copulatory stylets are long, with two slender, tapering and straight distal processes (Fig. 3 [A]-[B]; Crocker and Barr 1968,). While for *O. rusticus* copulatory stylets reach the base of the second periopods when the abdomen is flexed, the copulatory stylets of *O. virilis* are much longer and slender and reach all the way to the caudal border of the bases of the chilipeds when their abdomen is flexed (Fig. 3; from Crocker and Barr 1968). Further, the distal processes of the copulatory stylets in *O. rusticus* are deeply divided and slightly twisted, they are not in *O. virilis*, and the mesial process of *O. virilis* typically flattens to be 'spatulate' at the proximate end (Fig. 3; Crocker and Barr 1968).

DISTRIBUTION

NATIVE DISTRIBUTION

It is broadly accepted that *Orconectes rusticus* originated from a native range in the Ohio River and its tributaries (Girard 1852, Creaser 1931, Taylor and Redmer 1996, Fig. 6). Geographically, *O. rusticus* occupied lakes and rivers throughout Ohio, parts of Indiana and Kentucky (Creaser 1932, Page 1985).

NON-NATIVE DISTRIBUTION AND INVASION HISTORY IN UNITED STATES

By the 1970s, *O. rusticus* had spread to Wisconsin (Capelli 1975) primarily through bait-bucket introduction (Capelli and Munjal 1982). Capelli and Magnuson (1983) revealed a strong correlation between the presence of *O. rusticus* and human use in the 1970s and suggested introductions by anglers as the main vector. In the more recent years, *O. rusticus* has been spread by human activity as far north in the United States as Maine, south to Tennessee, and west as far as New Mexico (Page 1985, Hobbs and Jass 1988, Momot 1992, Taylor and Redmer 1996, Fig. 6).

NON-NATIVE DISTRIBUTION AND INVASION HISTORY IN CANADA

Crocker and Barr (1968) first recorded *O. rusticus* in 1963 from Long Bay of the Lake of the Woods (Ontario). However, further expansion of *O. rusticus* throughout the Kawartha Lakes district further east in Ontario has been further documented by Berrill (1978). At the time of Berrill's (1978) investigation, *O. rusticus* had established itself and achieved population numbers comparable to that of the native congener *O. propinquus* (Girard). Since the original accounts, *O. rusticus* has further expanded its range near Thunder Bay, Ontario, in the Lake Superior basin (Momot et al. 1988, Momot 1992, Fig. 6).

Crayfishes are easily transported overland and can be inadvertently introduced to new aquatic habitats when discarded as unused bait. For example, Rusty Crayfish introduction into the Lake of the Woods may have occurred via bait-bucket as this region is isolated relative to its range in the United States. However, the occurrence of *O. rusticus* in the Thunder Bay area has been attributed to its natural dispersion along the coast of Lake Superior from Minnesota (Momot 1992).

BIOLOGY AND NATURAL HISTORY

REPRODUCTION AND GROWTH

Copulation occurs in autumn and/or spring resulting in fertilization of the eggs that mature females extrude in spring and carry for a few weeks until they hatch (Berrill 1978). This stage is also described as "in berry" for the conspicuous presence of dark eggs attached to the abdomen of the female which can carry upwards of 200 eggs (Lodge et al. 1985). Young crayfish remain with their mothers through stages I and II, but leave when they molt into stage III, thus becoming independent in early summer. Young-of-the-year crayfish will molt several more times before autumn. Some will become sexually mature before winter, but most wait until the spring. These *Orconectes* crayfish males will molt out of sexually functional form I in the spring and back again from form II in middle or late summer while mature females molt only once after their offspring leave (Berrill 1978).

POPULATION DYNAMIC

The abundance of *O. rusticus* varies considerably between habitats and waterbodies, and is difficult to assess in the field; as such, to my knowledge there exists no reasonable estimate of the number of *O. rusticus*. Certainly, the reporting of a single specimen in a habitat indicates a much larger population as the ability of this species to hide in refuge likely consistently under-represents its population.

PHYSIOLOGICAL TOLERANCES AND BEHAVIOUR

Although little experimental information is available for the tolerance of *O. rusticus* to the suite of abiotic physiochemical characteristics of its environment, there does exist some analysis of the influence temperature, pH and oxygen have on this species (Capelli 1982, Berrill et al. 1985, Mundahl and Benton 1990).

The Rusty Crayfish are generally tolerant of thermal extremes, exposed to water in their native habitats ranging from near 0.0°C to an extreme of 39.0°C (Mundahl and Benton 1990). However, Mundahl and Benton (1990) do outline a preferred range between 20.0 and 25.0°C, and the authors suggest that this often results in adults forcing juveniles from preferred habitats into warmer waters causing the latter to be found in water 1.5 to 6.8°C warmer than adults. At temperatures exceeding 30.0°C adults have been observed burrowing in sand and gravel beneath rocks near the shore to escape the heat (Mundahl 1989).

In contrast to the broad temperature tolerance demonstrated by *O. rusticus*, this species suffers pronounced mortality under low pH conditions, at least in its juvenile stages (Berrill et al. 1985). For example, a pH range of 5.4–6.1 was experimentally shown to cause mortality to female-attached juvenile Rusty Crayfish although adult females did not seem to be affected by these acidic conditions (Berrill et al. 1985). Although Berrill et al. (1985) provide a good start toward learning the tolerance of this species, work is still needed to understand the response of *O. rusticus* to low pH. Aluminium and calcium concentrations in the water may also play a very important role in survivorship of young instar crayfish, particularly when the experiments were using soft water. The physiological responses and survivorship of *O. rusticus* to low pH may be increasingly favourable in more mineral rich aquatic environments around North America.

Only a single reference was found that describes *O. rusticus* dissolved oxygen tolerance from observational evidence of Capelli (1982) who comments that this crayfish appears to prefer well-oxygenated water. As such, more experimentation is needed to help clarify the habitat requirements and physiological tolerances of the Rusty Crayfish.

HABITAT

Taylor and Redmer (1996) conducted a study of *O. rusticus* dispersal in Illinois and found that this species preferred complex habitats. In both lakes and rivers, *O. rusticus*

usually occurred in areas with rocks or fractured concrete substrate, and distribution was limited by the presence of large cobble substrate. Further, Wilson et al. (2004) found that water depth limits *O. rusticus* movement and colonization as the species range expanded around the littoral zone of the lake and not from one side to the other.

There are few specific requirements documented for *O rusticus* reproductive habitat. However, the principal mating season for *O. rusticus* is during the period of seasonal cooling in September and October. Immediately following copulation, female *O. rusticus* construct horizontal burrows in the banks near the water line (Crocker and Barr 1968). It is possible that water level fluctuations may endanger gravid female *O. rusticus* during this time, but I could find no studies specifically addressing that possibility. Thus, there is no evidence of special habitat requirement for reproduction, outside of the refuge necessary for everyday protection, as the females keep the eggs with them.

FEEDING AND DIET

It is most likely that *O. rusticus* is an omnivore consuming a wide range of zoobenthic, aquatic plants and algal organisms occurring in the littoral zone of lakes and rivers. However, experiments attempting to determine the impact *O. rusticus* has on zoobenthos have had incongruent results (Lodge et al. 1994, Perry et al. 2000, Charlebois and Lamberti 1996, Perry et al. 1997, Stewart et al. 1998). McCarthy et al. (2006) recently compiled several short experimental studies using meta-analysis along with a long-term data set to identify consistent patterns of *O. rusticus* effects on aquatic invertebrate abundances. They identified decreases in abundance of Gastropoda, Odonata, Trichoptera, Amphipoda, Ephemeroptera, and Diptera in the presence of *O. rusticus*. Snails are particularly vulnerable to predation by *O. rusticus* (Lodge and Lorman 1987, Olsen et al. 1991, Lodge et al. 1994). These results are consistent with Wilson et al. (2004) who found similar impacts of *O. rusticus* on zoobenthos in a long-term study of a lake invasion.

Macrophytes themselves are typically considered poor food resources for crayfish (Momot 1984). The dramatic impact of *O. rusticus* on macrophyte biomass (Lodge et al. 1994) may actually be due to mechanical removal of macrophytes during the search for associated benthic fauna. This suggestion is supported by the apparent lack of interest crayfish subsequently pay to the detached macrophytes (Momot 1995). Those macrophytes that are ingested may serve as bulk filler in the absence of better food, as a substitute for higher protein food sources, as a source of micronutrients, or even incidentally ingested in the search for other organisms (Momot 1995). Whatever the reason for destruction of macrophytes by *O. rusticus*, it can be expected that macrophyte biomass will be reduced in newly invaded watersheds, potentially destabilizing the ecosystems.

IMPACTS ASSOCIATED WITH INTRODUCTION

Invading organisms are often particularly successful when their ecological niche is unoccupied in receiving ecosystems (Ricciardi and Atkinson 2004). Although there are several native crayfish species that fill the omnivorous, large invertebrate niche in southern Canadian lakes and rivers, the spread of *O. rusticus* is of special concern because of its ability to displace native congeners (Momot et al. 1978, Capelli and Munjal 1982). Thus, this species does not need an open niche to facilitate its invasion of new waterbodies. A clear example of this displacement ability comes from northern Wisconsin lakes wherein *O. rusticus* replaced two resident orconectid crayfish species to dominate the benthic crayfish fauna (Hill et al. 1993, and see Wilson et al. 2004). Observations such as these indicate that the presence of native crayfish already occupying similar habitats and diets will not act as a competitive buffer against prolific range expansion of *O. rusticus* as has been previously suggested by Crocker and Barr (1968).

Further, one notable distinction in the reproductive biology of this species over its congeners in temperate regions of North America is its ability to lay eggs at lower temperatures relative to competing crayfish, enabling a "head-start" in population growth for a season. Whereas *O. virilis*, for example, may only start laying eggs once water temperatures reach 11°C, *O. rusticus* can begin laying eggs at 4°C (Aiken 1968, Momot 1966, Weagle and Ozburn 1972, Berrill and Arsenault 1982). Although not explicitly described in these studies, *O. rusticus* young-of-the-year presumably leave their mothers earlier and develop earlier in the year too because of their early start. When considered in conjunction with the reproductive interference exerted by *O. rusticus* on other *Orconectes* species, the reproductive biology of this species help to enable its invasion characteristics.

Invasions of *O. rusticus* are of even more pronounced concern beyond the replacement of congeners as, once established, this species has been shown to impart dramatic ecosystem change beyond that possible in the presence of the former crayfish habitants (Wilson et al. 2004, Fig. 7). *O. rusticus* has a higher metabolic rate and higher rate of food consumption than its native congeners (Jones and Momot 1983), which in some situations may lead to pronounced reductions in benthic macroinvertebrates (Olsen et al. 1991, Momot 1992, Lodge et al. 1994) and macrophyte biomass (effectively eliminating whole macrophyte beds; Lodge and Lorman 1987). The large-scale removal of macrophytes by *O. rusticus* may further contribute to the reduction of macroinvertebrates by facilitating predation, altering fish habitat, and may even destabilize the aquatic ecosystem (Phillips et al. 2009).

Finally, *O. rusticus* has a high dispersal capability and, now that it is establishing in Canada's boreal region, it has a high potential to rapidly colonize connecting watersheds. Although highly variable, it is not exceptional for *O. rusticus* to travel 221 m in 48 h (Byron and Wilson 2001). Further, Puth and Allen (2004) determined that in addition to human activity, stream connections between waterbodies also played a significant role in *O. rusticus* invasion. This has important implications here in Canada

where point introductions to waterbodies, such as Lake of the Woods, may facilitate "jumps" across otherwise prohibitive watershed boundaries and allow *O. rusticus* to spread through connecting waterbodies.

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Figure 1. Rusty Crayfish (*Orconectes rusticus*). Photo credits: University of Minnesota Sea Grant Program, http://www.seagrant.umn.edu/ais/images_rustycrayfish

Figure 2. Morphological features of *Orconectes rusticus*. Adult crayfish with characteristic large claws, dark rusty coloured spots on each side of its body and about 12 cm in length, and characteristic subterminal dark band across large chelae (Picture courtesy University of McGill Biology Department).

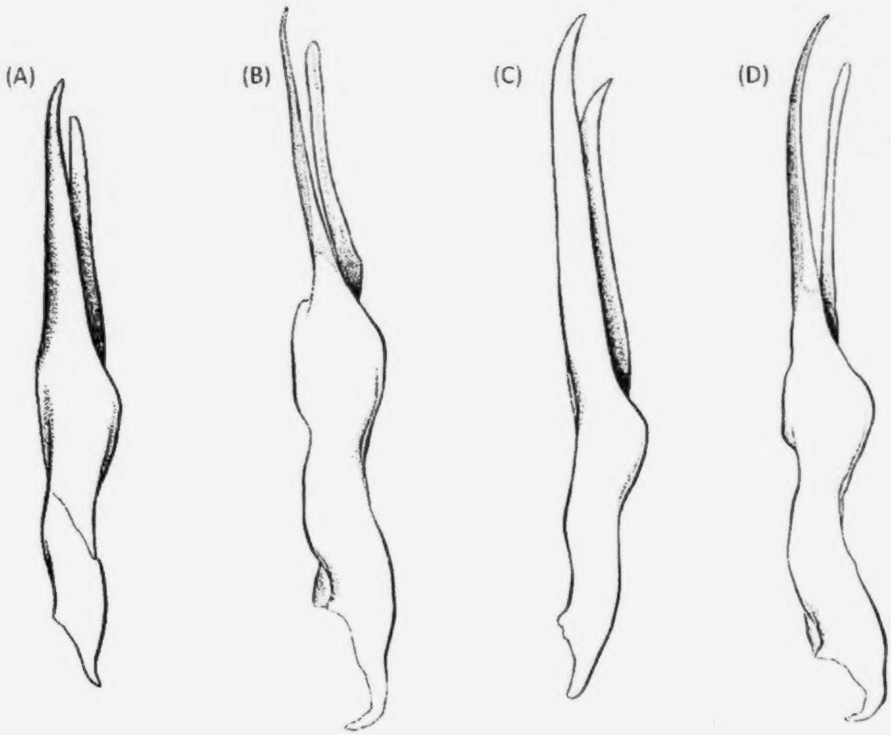

Figure 3. Lateral view of copulatory stylets from (A) Form I *Orconectes rusiticus*, (B) Form II *O. rusticus*, (C) Form I *O. virilis*, and (D) Form II *O. virilis* (Adapted from Crocker and Barr 1968).

Figure 4. Morphological features of *Orconectes rusticus*; rostrum without median carina (modified from Fetzner 2006, http://iz.carnegiemnh.org/crayfish/keys/orconectes.htm, accessed December 16, 2008).

Figure 5. Fingers of chela somewhat flattened and gap between them less than 1/4 width of palm (modified from Fetzner 2006, http://iz.carnegiemnh.org/crayfish/keys/orconectes.htm, accessed December 16, 2008).

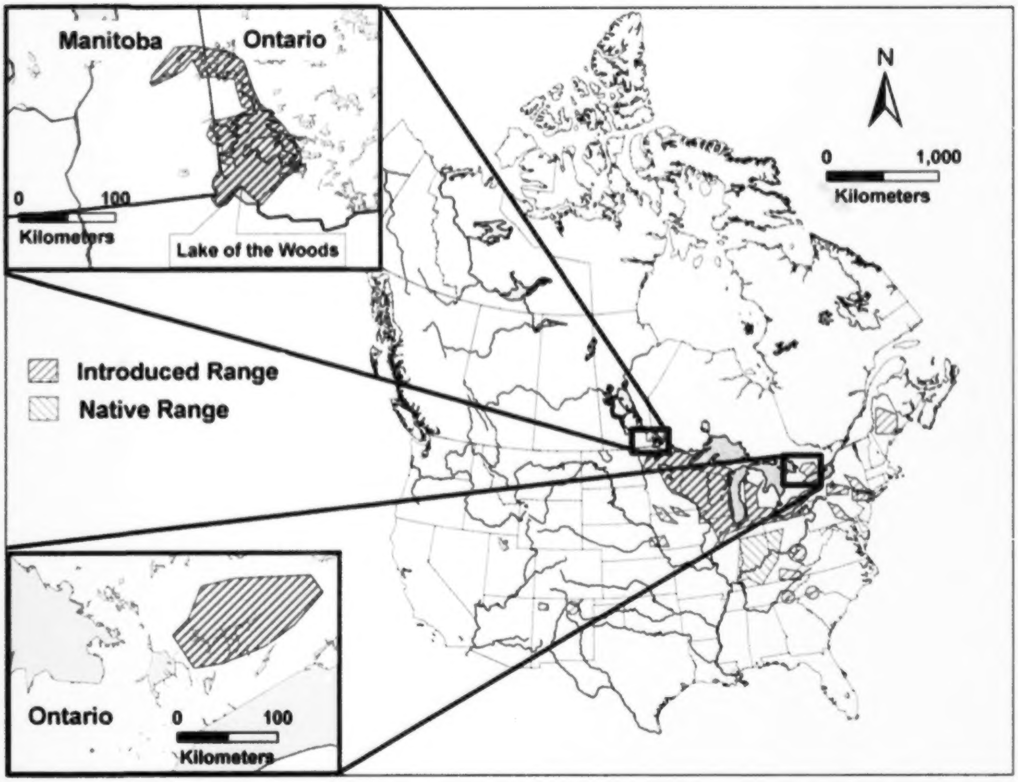

Figure 6. Distribution of *Orconectes rusticus* in Canada and the United States (United States Geological Survey 2009). Insets are focused invasion front areas of Lake of the Woods in North Western Ontario (top) and Kawartha Lakes district, Ontario (bottom).

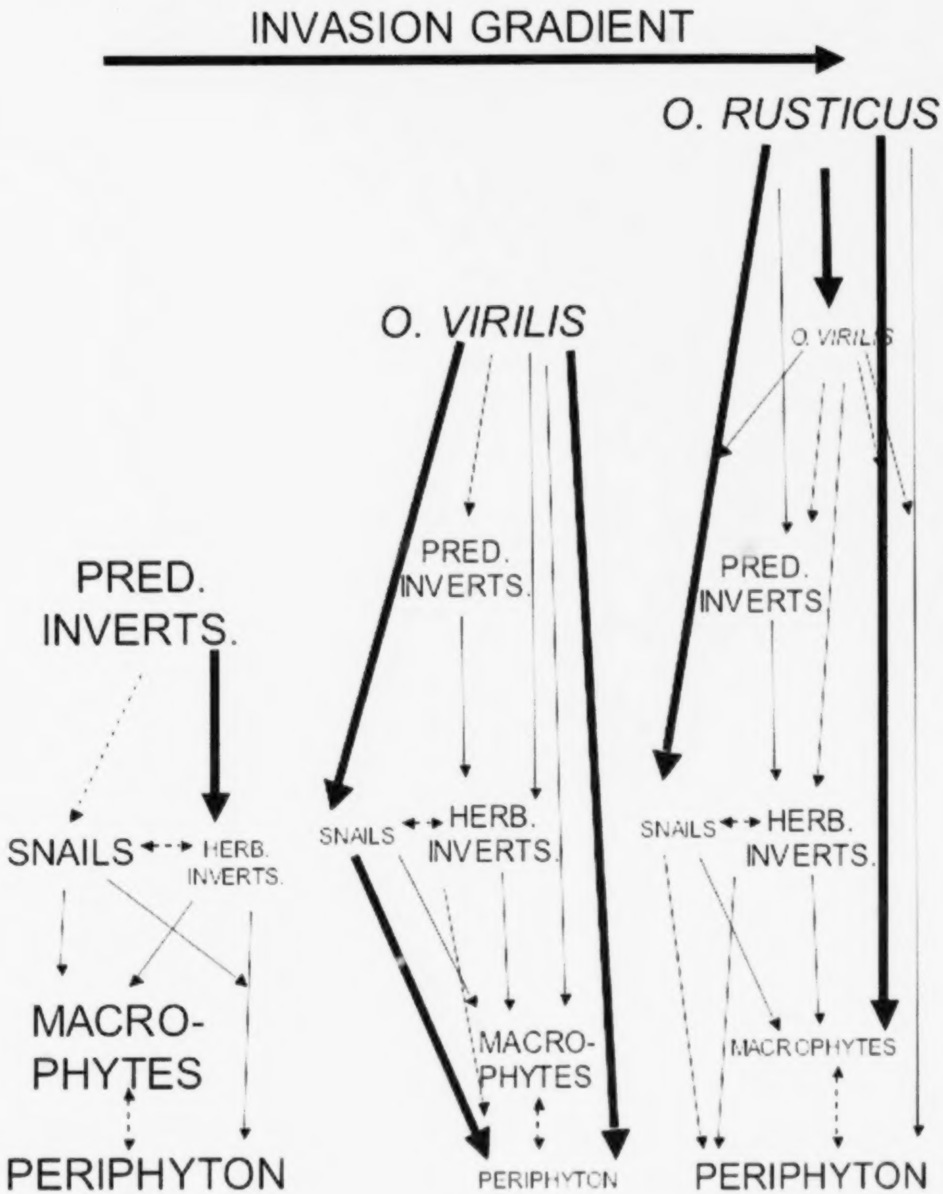

Figure 7. Simplified trophic relationship food web for the littoral zone of boreal lakes over an invasion gradient (no crayfish – most common native species in Canada, *O. virilis*, and – *O. rusticus*). Bold arrows indicate strong interactions, solid arrows moderate interaction, and hashed-line arrows weak interaction. Hashed arrows indicate competition in both directions. PRED. INVERTS. = Predatory invertebrates, HERB. INVERTS. = Herbivorous invertebrates (from Phillips et al. 2009).